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Automatic Intercept System:

Peripheral Circuits

By P. J. BRENDEL, W. K. COMELLA, R. N. MARKSON, P. J. MOYLAN, and J. OROST

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The Automatic Intercept System forms intercept announcements from phrases recorded on a magnetic drum by means of a sequence of connections through a time division switching network. Automatic fault recovery and diagnostic maintenance features include a trunk test circuit that enables maintenance programs to look in at the system on trunk pairs and test the autonomous scanner and time division network as well as the trunk and service circuits.

The Automatic Intercept System time division switching network, announcement machines, operator positions, trunk and service circuits, and the maintenance strategy for these units are described in this paper.

I. INTRODUCTION

An Automatic Intercept Center (AIC) consists of a processor and associated peripheral circuits as shown in Fig. 1. An Automatic Intercept System (AIS) may consist of up to four of these AIC's.[1] One AIC is designated home and the others are termed remote. The home AIC has associated with it a Centralized Intercept Bureau (CIB) which may be located in either the same or a distant building. The peripheral circuits of the AIC and CIB and the maintenance programs for these circuits are described.

1.1 Peripheral circuits of an AIC

Trunk circuits interface local offices, operator positions, and service circuits with the time division network of the AIC. Maintenance programs automatically test the trunk and service circuits using facilities of the trunk test frame.

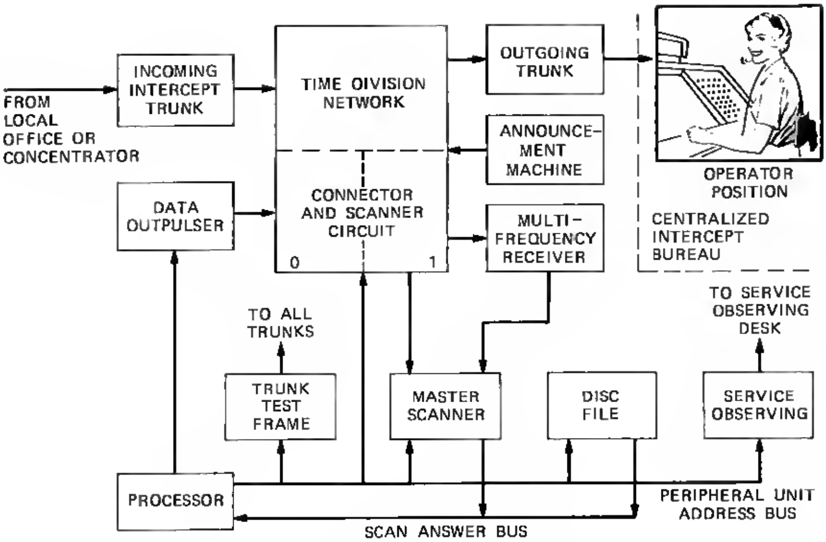

Fig. 1—Automatic Intercept Center.

An announcement macbine contains prerecorded words and phrases which are combined to form a spoken message notifying the customer of the status of an intercepted number.

An AIC may he equipped with either one or two time division networks. A time division network is comprised of two connector and scanner circuits, each connector providing 32 talking time slots. The scanner autonomously scans and records the on- or off-hook status of all trunks, reporting changes of state to the processor via the master scanner.

The master scanner used hy the processor to input data is the same as that used in tbe No. 2 Electronic Switching System (ESS) and has been previously described.[2]

1.2 Maintenance programs

Failures in the peripheral circuits are automatically detected through hardware and program checks. In general, the strategy is similar to that used by No. 2 ESS.[3] Major circuits are duplicated and if a failure occurs a working configuration is automatically established in which the faulty circuit is removed from service. Automatic diagnostics then locate tbe trouble within the faulty circuit to expedite repair, minimizing the interval during which the system operates on only balf of a duplicated pair.

II. TRUNK AND SERVICE CIRCUITS

Each trunk circuit in the AIC is packaged on a single plug-in circuit pack. The trunk circuits interface the tip and ring of intercept lines, service circuits, and operator position to the time division network. The switching network is distributed; most of the time division switches (TDS) are contained in the trunk circuits. Trunk test arrangements provide access to the tip and ring allowing maintenance programs to test through the trunk circuit into the network. A husy condition can be returned to the local office preventing calls on the trunk while it is under test or out-of-service.

The AIC has both incoming (originating) and outgoing (nonoriginating) trunks. The trunks are classed according to the type of service which they perform. A "type number" in a call store area dedicated to each trunk indicates the class of the trunk. Tahle I lists the various originating and nonoriginating trunk types.

2.1 Originating trunks

Traffic to the AIC is generated when a call terminates at an intercepted line in a local office. The line number is identified and outpulsed to the AIC which determines the status of the numher from

Table I — AIS trunk types

Type Number	Trunk Type
Originating	
01	Incoming Intercept ANI
02	Incoming From CIB Operator
03,12,13,14	Incoming Directory Assistance
04	Incoming From Remote AIC
05	Incoming Intercept 3 Class ONI
06,07	Spare
10,15,16,17	Incoming Intercept I Class ONI
11	Incoming Operator Training
Nonoriginating	
20,31,33,34,35	Spare
21,22	OGT to Trouble Operator
23	OGT to Supervisor
24	OGT to ONI Operator
25	Operator Training *Touch-Tone*® Receiver
26	OGT to Home AIC
27	OGT to CIB Operator
30	MF Receiver Trunk
32	Data Outpulser
36	Miscellaneous and Test Trunks
37	Unequipped or Unassigned Trunk Location

information stored in the disc file and returns an appropriate announcement to the customer. Under this method of operation, called Automatic Numher Identification (ANI), the numher *actually* reached hy the customer is announced.

There are three main classes of intercept: machine, trouhle, and regular. Unequipped line numhers are placed on machine intercept; essential lines which are temporarily in trouhle are placed on trouhle intercept; changed or disconnected numhers are placed on regular intercept. On the ANI trunk these classes are indicated hy a class digit prefixed to the called numher by the local office.

2.1.1 ANI trunk

Figure 2 shows a typical trunk circuit used in the AIC. Each trunk has a unique address hased on its physical appearance on the network. Trunks appear in groups; vertical and horizontal numhering is used to distinguish trunks within a group. In order to estahlish a connection, a coincidence of pulses is required on the G, V, and H (group, vertical, and horizontal) leads from the connector translator. This causes the hilateral switch to close completing the connection to the time division network. The connection hetween the trunk and the time division hus is estahlished repetitively for a short period of time called a time slot. Energy is interchanged hy the resonant transfer principle[4] with another trunk circuit which is selected during the same time slot.

On-hook and off-hook information is received over the trunk pair and detected hy the trunk current detector. Any transient hit on the trunk is filtered hy this detector. A different time slot, known as the

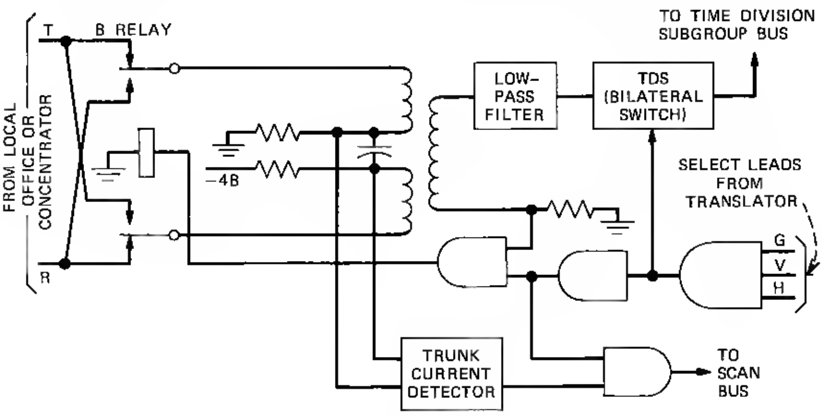

Fig. 2—Trunk circuit.

scan interval, is used to pass this information over the scan hus. In contrast to other switching systems, the talk selection and scan selection are integrated into a common set of leads (G, V, H). This results in a less expensive and more reliahle arrangement. However, this also made it nccessary to inhihit the hilateral switches during the scan interval to prevent a douhle access which would affect the resonant transfer and cause a high-pitched whistle in the talking connection.

When an intercepted line is reached, the local office transmits the called numher digits to the AIC hy multifrequency (MF) pulsing. The ANI trunk uses reverse hattery supervision. Outpulsing is started hy means of a wink signal which is controlled hy the B relay of the trunk. This relay operates when the trunk is placed in a time slot and sends a hattery reversal to the local office. After a timed interval the multifrequency receivcr (MFR), which has heen connected to the trunk in the same time slot, sends a signal through the time division network, causing the B relay to release completing the wink. The start of the wink signal tells the local office the AIC has attached an MFR; the end of the wink signal indicates that the MFR is ready to receive pulsing.

2.1.2 Operator Number Identification (ONI) trunk

Some offices do not have the ahility to automatically identify the called number. For these offices an arrangement is provided whereby an operator at the AIS may ask the customer for the called numher and key this numher into the AIC. These calls are hrought into the AIC via an ONI trunk which responds to three distinguishing signals to differentiate the three classes of intercept. This signaling is accomplished hy means of various hattery conditions on the tip and ring conductors. Two additional scan buses are used to convey these three classes of intercept to the processor. After an off-hook has heen received via the regular scan hus the processor must initiate a directed scan over the other two buses to fully identify the class of intercept. The processor will then act to set up the proper connection. Blank numher intercept calls may he immediately given a hlank numher announcement. A regular intercept call must first go to an ONI operator. This operator will inquire as to the called numher and key this numher into the AIC. The call will now proceed as if it were an ANI call. To accommodate offices which are not arranged to forward the class of intercept, a one-class ONI trunk is also provided which gives all calls regular intercept treatment.

The ONI arrangement has the drawhack that the announcement that the customer receives is for the numher he *thinks* he dialed and not the numher which he actually reached. The customer is also affected hy operator keying errors. In addition, since ahout 60 percent of the traffic from an ONI office is regular intercept and each of these calls requires the intervention of an operator, this type of traffic is expensive to handle.

2.1.3 Miscellaneous

Other incoming trunks used at the AIC are for directory assistance, CIB inquiry, operator training, and incoming trunks from remote AIC's. The operator inquiry trunk interfaces the CIB with the AIC for such reasons as disc file interrogation and calls to the supervisor. The operator training trunk is used to simulate an intercept call to a trainee.

Since the remote AIC does not have a CIB, traffic intended for operators is sent to the home AIC which tandem switches this traffic to the CIB. This traffic is handled at the home AIC over incoming trunks from the remote AIC.

2.2 Concentrators

The AIC is arranged to accept calls from local or distant concentrators. The concentrator used with the AIC is the 23 type.[5] These concentrators have heen modified to pass ANI or ONI type traffic to the AIC. For ANI traffic the concentrator repeats supervisory signals in hoth directions. In the case of ONI traffic, the concentrator converts the dc signal which identifies the class of intercept into MF tones and passes these tones to the AIC.

2.3 Outgoing trunks to operators

Outgoing trunks provide access to ONI positions, CIB positions, trouhle operators, and the supervisor.

In most cases the circuit pack used for these trunks is the same as that used for the ANI trunk previously described. However, a special arrangement is used to provide full access to a single operator hunt group in a two-network AIC. As shown in Fig. 3, a hack contact of the B relay in the trunk circuit on network 1 is used to transfer to the trunk circuit in network 0. The B relay operates when the trunk is placed in the time slot. Since only one of these two trunks is placed in a time slot at a given time, the position is automatically associated

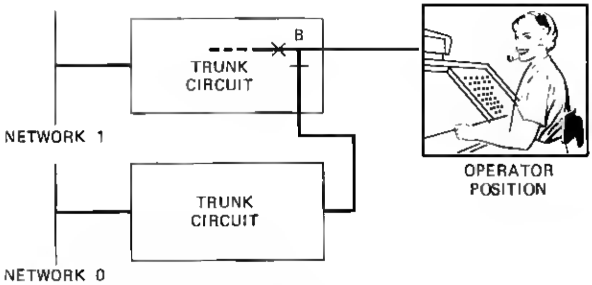

Fig. 3—Transfer arrangement for operator trunks.

with the appropriate network and the other trunk circuit is cut off from the pair.

2.3.1 Outgoing trunk to home AIC

The remote AIC has outgoing trunks to the home AIC. As previously described, these trunks provide access to the CIB operators via the switching network of the home AIC.

In contrast to the operator trunks, if the remote AIC has two networks, full access is not provided to these trunks. Instead, two hunt groups are provided, one per network. This requires a few more trunks between the remote and home AIC than a single large group would. However, two hunt groups use fewer appearances on the remote AIC networks than would be required if full access to a single large group were provided using the transfer trunks which are used for outgoing trunks to operators as described above.

2.4 Service circuits

Service circuits send and receive data and perform other specialized functions. Among the service circuits used in the AIS are the MF receiver, *Touch-Tone*® receiver, data outpulser, and audible ring circuit.

2.4.1 Multifrequency receiver

The MF receiver circuit is a one-digit receiver and is used to receive class of intercept and called number information from the local office and to receive similar information from the CIB positions. Multifrequency pulsing uses voice-frequency tones in a 2-out-of-6 code. These tones are detected by the MFR which forwards the coded information for each digit to six ferrods on the master scanner (Fig. 4). The master scanner provides a means to input information to the

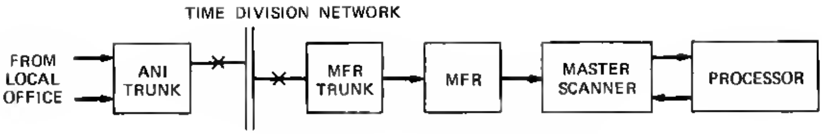

Fig. 4—ANI trunk to MFR connection.

processor. Each MFR has a dedicated register in call store memory. The input-output (IO) circuit within the processor autonomously looks for digits on tbese ferrods every 10 milliseconds and transfers them to the register in call store.

A diagnostic program is provided to aid in multifrequency receiver maintenance. This program, which runs under tbe control of a trunk and service circuit maintenance control program described below, can be requested to run by various methods. Particular types of errors encountered by the digit processing program will automatically cause a diagnostic to be run on the MF receiver involved witb the error. Examples of these errors are insufficient or too many digits received for a given class of call, failure of a 2-out-of-6 tone check for each digit, or no digits received. In addition to these MF receiver error detection cbecks, tbe receivers are periodically exercised by a trunk exercise program which continuously tests most trunks in tbe system. The MF receiver diagnostic tests the ability of the MFR to receive all six tones and to correctly supply the wink control signal used for signaling the local office to start outpulsing. It also cbecks for any false outputs and makes power checks.

2.4.2 Data outpulser

Prior to connecting a customer to the operator, the processor connects a data outpulser to the outgoing trunk to the CIB position and sends all known information about tbe call to a display circuit located in the position. The data are encoded in a BCD format and are sent in a serial train of 94 bits using frequency-shift pulsing at frequencies of 1150 and 1850 Hz. A buffer area in call store is dedicated to each outpulser. The program loads information for eacb outpulser into the appropriate huffer and the IO circuit within the processor autonomously sends the information in the huffers one hit at a time over a private pair to a flip-flop located in each outpulser, as shown in Fig. 5. A 1.25-millisecond clock gates the data from this flip-flop to a register. Depending on tbe state of this register, tbe frequency-shift modulator will send one of two frequencies corresponding to a zero

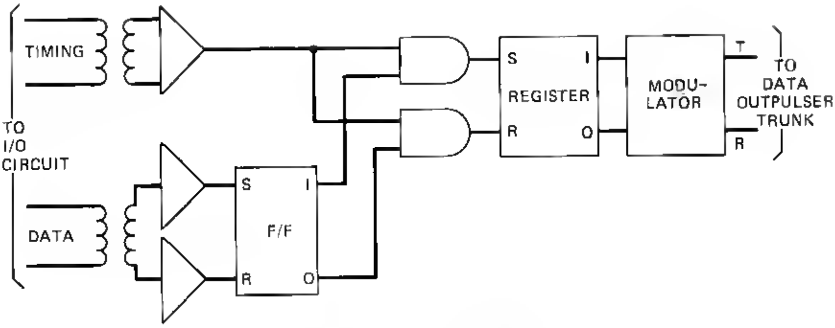

Fig. 5—Data outpulser.

or a one. After the message is received on the operator's display, the data outpulser will be momentarily connected to the operator's telephone circuit. This generates a "zip tone" or altering tone apprising the operator of a new call.

2.4.3 Miscellaneous

The *Touch-Tone* receiver is used in conjunction with the operator training circuit and is quite similar in its operation to the MF receiver circuit. This receiver is required since the *Touch-Tone* card dialer used in operator training emits *Touch-Tone* frequencies, as described in a subsequent section.

The audible ring circuit is used to send ringing tone to a customer who is waiting for an operator. This action tells the customer that his call is proceeding normally.

2.4.4 System monitor circuit

As a backup check on the ability of the AIC to process calls, a wired logic circuit known as the system monitor circuit periodically originates a call. This time period is optionally either 30 or 60 seconds in duration and the length of the calls is optionally either 5 or 10 seconds. During the time that the call is originated, this circuit will check the ability of the AIC to find an MF receiver and generate a wink signal. Each time this circuit successfully completes its call, a peg count is scored. If a call is not able to complete, an error register is scored and a major alarm sounded. This alerts the maintenance personnel if the AIC has not automatically recovered from some failure which prevents calls from being handled.

2.5 Trunk maintenance

The trunk test circuit provides the hardware features required to perform various kinds of program-controlled trunk maintenance.

2.5.1 Trunk test circuit

The trunk test circuit provides access to the tip and ring of each trunk circuit. Figure 6 shows an incoming trunk and its associated MB and TT relays. The operation of the MB relay splits the tip and ring from the trunk and connects a make-husy condition toward the local office, preventing origination of new calls on the trunk. Operation of the TT relay connects the signaling and termination circuit to the tip and ring of the trunk. This circuit is multipled to all 415 trunks through their corresponding TT relays. A 1-out-of-N check circuit controls two ferrods which indicate to the program that the MB and TT relays of one and only one trunk have operated. Once the signaling and termination circuit is connected to a trunk, marginal tests can he applied to that trunk. Off-hooks, on-hooks, various battery conditions, and 1000-Hz tone can he applied to the trunk. A ferrod (SIG

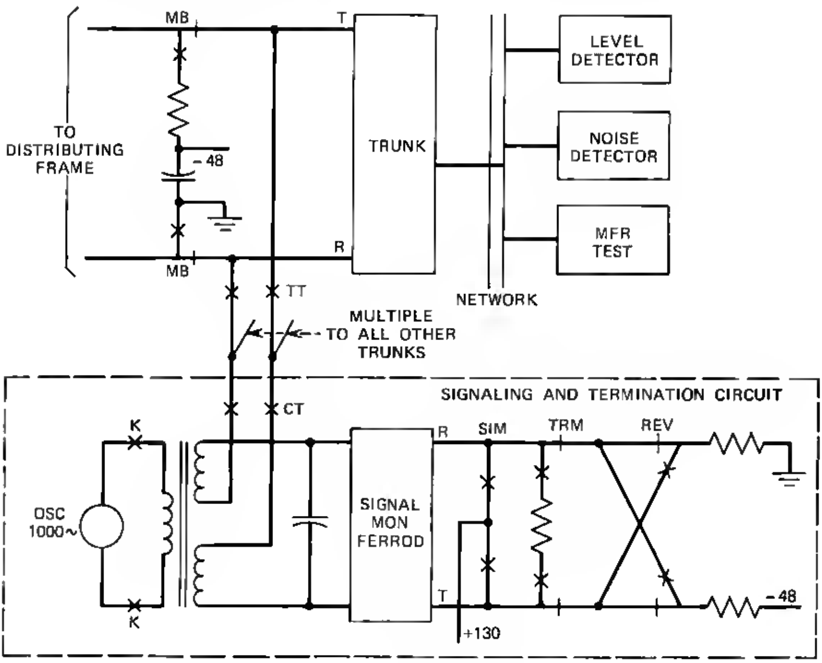

Fig. 6—Trunk testing.

MON) allows the program to monitor dc currents flowing in the tip and ring of the trunk under test.

Three test trunks, the noise detector, level detector, and MFR test circuit, have separate network appearances and are used in testing the trunks and MF receivers. The level detector can be connected through the network to the trunk under test and indicates the presence of tone via a ferrod. The level detector and tone supply are set to detect a trunk which develops a loss of more than 3 dB. Likewise, the noise detector is used to detect noise in the trunk or the network. The MFR test circuit is connected through the network to an MFR under test and can outpulse both normal and illegal multifrequency codes and test the MFR under marginal operating conditions.

2.5.2 Trunk maintenance programs

Trunk diagnostics can be automatically initiated in response to detected failures or they can be manually requested by means of appropriate input messages from a maintenance teletypewriter. When no other maintenance has been requested, routine trunk exercises are run. This background trunk exercise, which tests every trunk every few hours, also provides a powerful detection mechanism for network troubles. The sequence of trunks which is exercised is determined by a pattern based on the network appearance (GVH). This pattern was chosen to test many different portions of the network in a short period of time. The trunk maintenance programs also permit maintenance personnel to remove and restore trunks and service circuits and to run selected portions of diagnostics called blocks and segments.

2.5.2.1 Maintenance control hierarchy. The trunk maintenance programs run under a trunk and service circuit maintenance control program. The trunk control program is a client of the switching equipment maintenance monitor which runs under the system maintenance monitor (see Fig. 7) described elsewhere in this issue.[6] The switching equipment maintenance monitor controls the scheduling of maintenance activities for the master scanner, network, and trunk and service circuits; buffering requests for these programs; and executing them in order of priority.

2.5.2.2. Trunk diagnostic table. Different trunk diagnostics must be provided for each trunk type (ANI, ONI, operator, etc.). A table-driven approach was utilized to facilitate the implementation of these different diagnostics. There is a different diagnostic table for each type of trunk or service circuit. As shown in Fig. 8, the trunk network

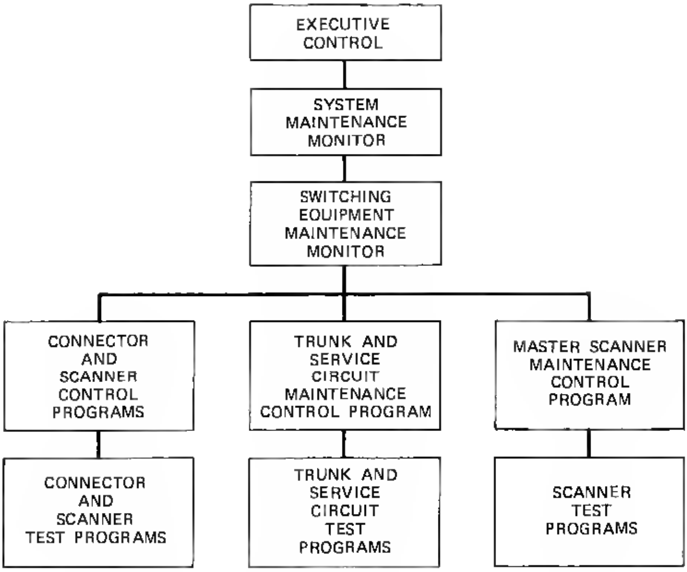

Fig. 7—Maintenance control structure.

appearance (GVH) is used to index a table of office parameters to determine the type of trunk. Tbe type number is then used to obtain tbe address of the diagnostic table pertaining to tbat trunk type.

Each table consists of a list of tests or functions to be performed. Tbe trunk control program executes eacb function in tbe order in which it appears in the table. Eacb function consists of a small program, similar to a subroutine, which performs a single task such as connecting a trunk to the level detector. Figure 9 sbows a diagnostic table and the linkages between it and tbe function programs and subtables described in a following section. As tbe tasks performed by most functions are generic, tbey may be used as building blocks in many different diagnostics. Functions whicb cbeck results make use of a data word wbicb is also placed in the table as a separate entry immediately following tbe function entry. This tecbnique permits a function to be used in many different test situations.

Diagnostic failures are identified by a block and segment number. A typical diagnostic consists of about nine blocks of tests arranged in numerically increasing order, each block containing several segments. Each function is assigned a unique segment number regardless of the order in wbicb it appears. Tbe segment number identifies tbe specific function that failed within tbe block.

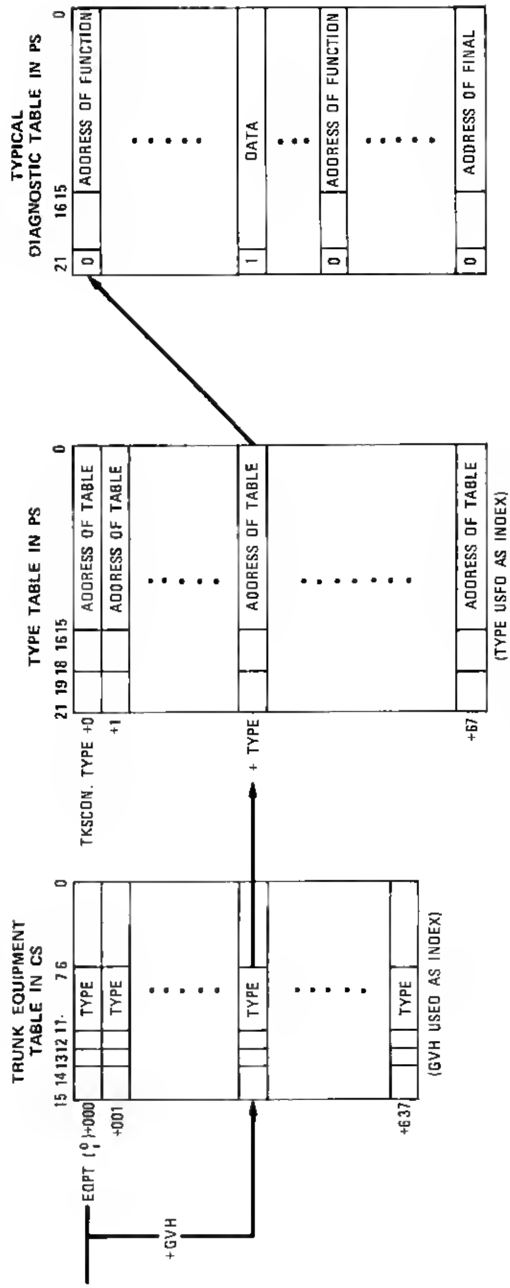

Fig. 8—Trunk diagnostic table selection.

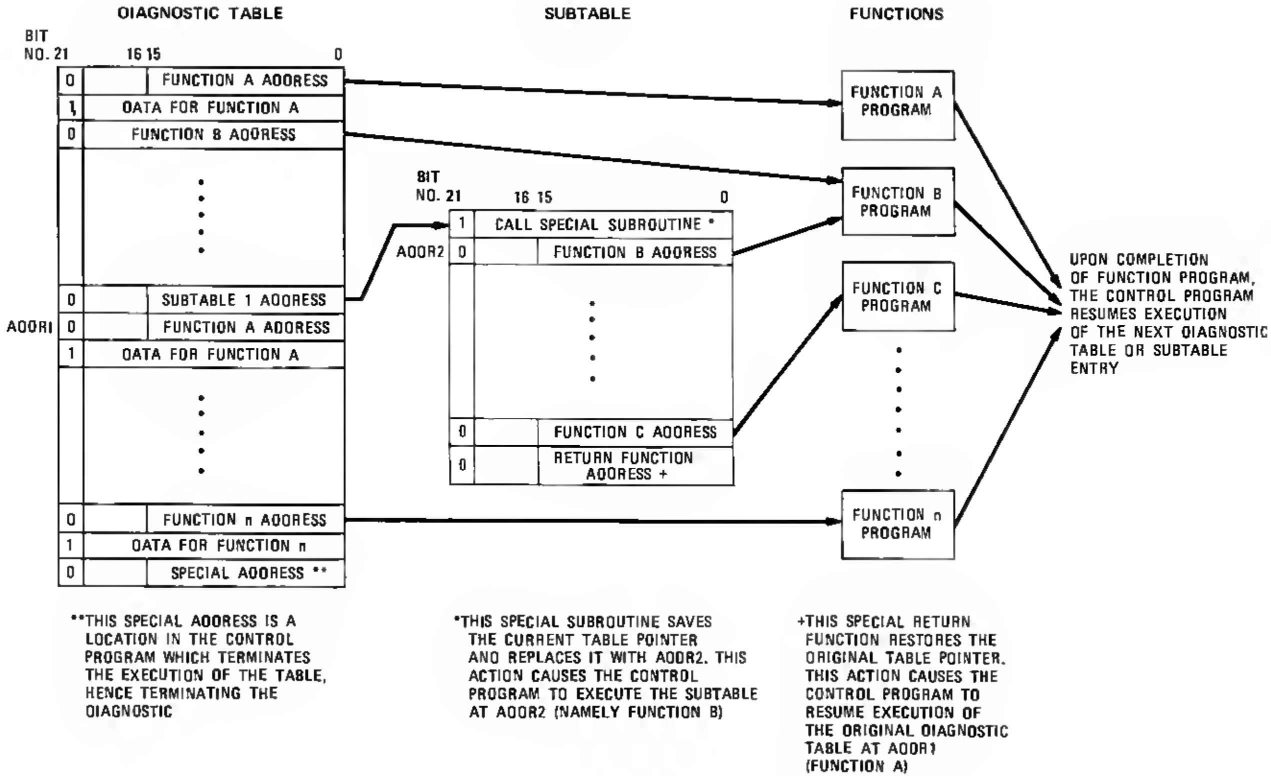

Fig. 9—Trunk diagnostic table execution.

The diagnostics are ordered so that small portions of the circuit are checked and verified and may be assumed good for subsequent tests which check features of increasing complexity. For example, some checks are made on the trunk test frame before attempting any tests. Continuity of tip and ring are verified before attempting transmission checks. Transmission is checked before attempting scans of supervision as the transmission check verifies the translators of the trunks, and scans will not work unless tbe translators are good. The ordering of tests allows fairly definite conclusions to be drawn as to what is causing a particular fault.

2.5.2.2.1 Subtables. A subtable feature is incorporated in tbe trunk and service circuit maintenance control program to permit tbe use of a common sequence of functions in several different diagnostic tables. Common test sequences are useful wben tbe nature of the test is independent of the trunk type; for example, the transmission check. A subtable consists of an ordered list of functions similar to the diagnostic tables previously described. To cause a subtable to be executed, a function is used which cbanges pointers in a call store area, directing the control program to tbe subtable (see Fig. 9). A similar tecbnique is used to return from tbe subtable to the diagnostic table.

2.5.2.3 Permanent signals. If a trunk remains off-hook for more than two minutes after the operator bas released, a permanent-signal condition is suspected. Tbe trunk is diagnosed to verify that the trouble is not within the trunk circuit at the AIC. If this diagnostic passes and the trunk is still off-hook, the trunk is placed in the permanent-signal state. When permanent-signal trunks go on-hook they are automatically returned to service.

2.5.2.4 Pumping trunks. Since the ANI trunk previously described uses reverse battery supervision, certain types of faults can occur which require a special detection mecbanism. For example, a grounded ring will cause the trunk to go off-book, but wben it is placed in a time slot and the battery reverses it goes back on-book. Thus a pumping condition develops in which a trunk generates rapid seizures of short duration, tying up equipment and creating unproductive work for the system. To detect this situation, a special subroutine bas been included. Whenever a trunk goes on-hook shortly after being placed in a time slot, call processing calls this subroutine. Tbe subroutine keeps a record in call store of the previous trunk it was called for and, if this matches the present trunk, it is considered to he pumping. This call storc record is erased every six seconds and so for a trunk to he considered pumping, it must go on-hook shortly after heing placed in the time slot twice within a six-second interval. In addition to outputting a special "PUMP" message, these trunks are removed from the time slot and placcd in the suspected permanent-signal state, as descrihed ahove, from which they will he diagnosed and eventually placed in the permanent-signal state.

2.5.2.5 Trunk out-of-service states. When an automatically requested diagnostic fails on a trunk, an attempt is made to remove it from service. For intercept trunks a threshold constant is checked. If the total number of automatically made-husy trunks equals that threshold, usually set to one less than the smallest trunk group, then no more intercept trunks are automatically made husy. When a trunk is removed from service, the MB relay is operated, sending a make-husy condition on the tip and ring to the local office.

By means of an appropriate TTY input message, any trunk, service circuit, or operator position can he removed from service or restored to service.

2.5.2.5.1 Trunk out-of-service displays. The status of AIS intercept trunks is displayed on lamps located on the supplementary maintenance frame key and lamp panel as shown in Fig. 10. This panel contains status lamps pertaining to the networks, files, and trunks. Red lamps indicate power-off conditions on the networks and files. White lamps indicate activc connector, scanner, announcement machine, clock, and file. The row of lamps indicating trunk status provides indications of any off-normal conditions as well as any excessive trouhle conditions. These lamps indicate if any (OS) or an excessive numher (XOS) of incoming intercept trunks are out-of-service either manually or automatically, if any (PER) or an excessive numher (XPER) of trunks are permanent signals, and if any (AMB) or an excessive numher (XAMB) of trunks have automatically heen made husy. In addition, operation of the MB relay of a trunk causes a lamp on the faceplate of the trunk circuit pack to light, facilitating location of the circuit pack on the frame.

III. ANNOUNCEMENT MACHINES

Natural-sounding voice messages which inform the customer of the status of an intercepted numher are formed hy piecing together prerecorded words and phrases. These words and phrases are recorded

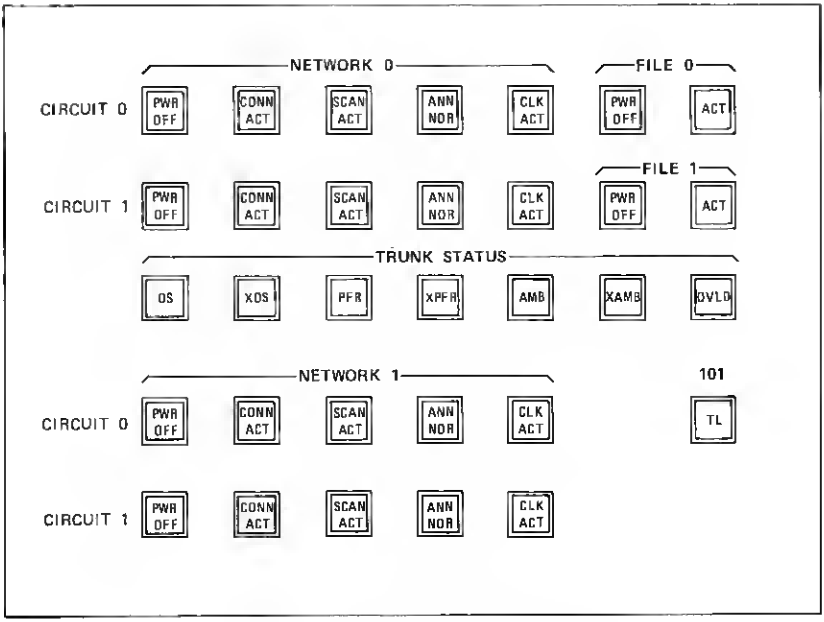

Fig. 10—Supplementary maintenance display.

on the rotating drum of a 96-track announcement machine. Two announcement machines are provided for reliability.

3.1 Announcement trunks

The output amplifier of each track is connected directly to an announcement trunk on the network. For a two-network AIS the same output is multipled to an announcement trunk on the other network, as shown in Fig. 11. Since many incoming trunks, using different time slots, can be connected to one announcement trunk, the time division switch in the announcement trunk is interrogated at a rate which varies, whereas an incoming trunk which is used on a single connection in one time slot is interrogated at a fixed rate. Therefore the resonant transfer principle cannot be used in the announcement trunks; instead, the audio signal from the announcement machine is sampled. This trunk is designed to insure high echo and singing return losses, low crosstalk, and high talk-through suppression.

3.2 Message synthesis

The announcement is assembled by establishing a sequence of connections through the connector and scanner between the incoming

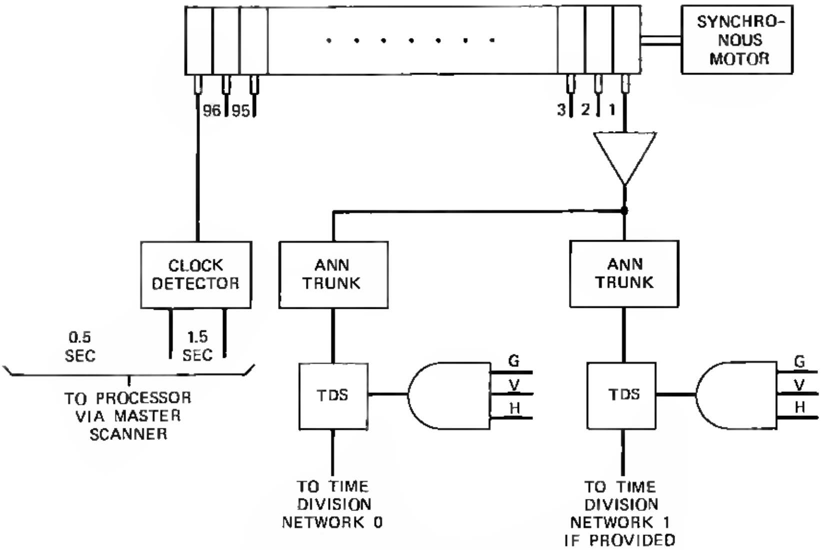

Fig. 11—Announcement machine.

trunk and the appropriate announcement trunk. By using the time division network in such a role, expensive hardware message synthesizers are not required, thereby reducing the cost and simplifying the maintenance of the announcement machine.

3.2.1 Vocabulary

The 96 tracks consist of either 0.5-second or 1.5-second phrases and provide a vocabulary of about 170 words. The 1.5-second tracks are used for phrases such as "The Numher You Have Reached" or "Calls Are Being Taken By." The 0.5-second tracks are used for the digits 0–9, letters, and words such as "Hundred" or "Thousand." Two tracks are provided for each digit, one recorded with a neutral inflection, one with a falling inflection. The falling inflection is used at the end of a string of digits preceding a pause to enhance the naturalness of the message.

Tracks 1 to 48 are standard and are the same for all installations (see Tahle II). The recordings on tracks 49–96 are specified by the telephone company when a system is ordered. These tracks may be used to record locality information or to record letters if all-number calling is not heing used.

Table II — Announcement machine tracks

Track No.	Phrase or Digit
1	The Number You Have Reached
2	Has Been Changed
3	The New Number Is
4	To a Nonpublished Number
5	For Incoming Calls
6	In Area Code
7	Has Been Disconnected
8	To a Nonlisted Number
9	Temporarily
10	At The Customer's Request
11	Is Being Changed
12	The New Number
13	Is Not Yet Connected
14	(Pause)
15	Calls Are Being Taken By
16	Is Not In Service
17	Is a Working Number
18	Please Check The Number
19	And Dial Again
20	If You Need Assistance
21	Please Make a Note of It
22	You May Stay on the Line
23	And An Operator Will Answer
24	Thousand
25	Hundred
26 to 35	Digit 0 to 9 With Neutral Inflection
36 to 45	Digit 0 to 9 With Falling Inflection
46	(Reorder Tone)
47	Area Code
48	Will You Dial It Again, Please
49 to 96	Locality name as required, for example, "In Freehold"

3.2.2 Phrase timing

The drum rotation period is 4.5 seconds. There are three repetitions of a 1.5-second phrase around the periphery of the drum and nine repetitions of the 0.5-second phrase. All tracks are synchronized and a 97th track is recorded with tones which indicate the start of each phrase. These tones are converted to dc signals which are read via the master scanner; when a new phrase begins, a new network connection is made by the processor.

3.3 Maintenance

Maintenance programs monitor power and fuse alarms, the rotational speed of the drum, and the output level of each track. Power failures or blown fuses are detected via master scanner ferrods. The rotational speed is checked by a program in the timed 25-ms input-output (IO25) interrupt which times the phrase-synchronizing clock pulses. Faults in individual tracks are detected by announcement trunk exercises which are interleaved with other trunk exercises. An individual track is connected through the network to the level detector which was previously described. The test program synchronizes with the beginning of a phrase and checks the output of the detector every 25 ms for the duration of the phrase. This is necessary since the detector indicates level present only during peaks in the voice signal. To insure that a failure is reported only when a failure actually exists, the level detector is set so that a phrase containing a small amount of energy, such as the digit "eight," will not be reported as bad unless the output level falls by at least 7 dB. Upon detecting either a power, timing, or track level failure, the faulty machine is removed from service and the duplicate machine handles all announcements.

3.4 Special announcement machine

A special announcement machine has been provided to permit local recording of announcements to meet special situations. Calls may be directed to this machine by entering the appropriate status for the numbers in the disc storage file.

IV. NETWORK

The AIC interconnects trunks using time division switching circuitry similar to that developed for No. 101 ESS.[7] The AIC can have either one or two time division switching networks depending upon the amount of traffic. A network may be equipped with 415 trunks for use with incoming intercept trunks, service circuits, operator positions, etc., in addition to 96 duplicated announcement trunks. Each network provides 64 time slots and contains two connector and scanner circuits, each capable of controlling 32 connections and monitoring the supervisory state of all 415 trunks of a network.

4.1 Network topology

Each network interconnects trunks via a grid of time-shared subgroup buses and two intergroup buses as shown in Fig. 12. Full access is not required between the two networks as only the announcement machines and operator positions serve both networks. As previously described, announcement tracks are multipled to both networks and full access to operator groups is achieved through a

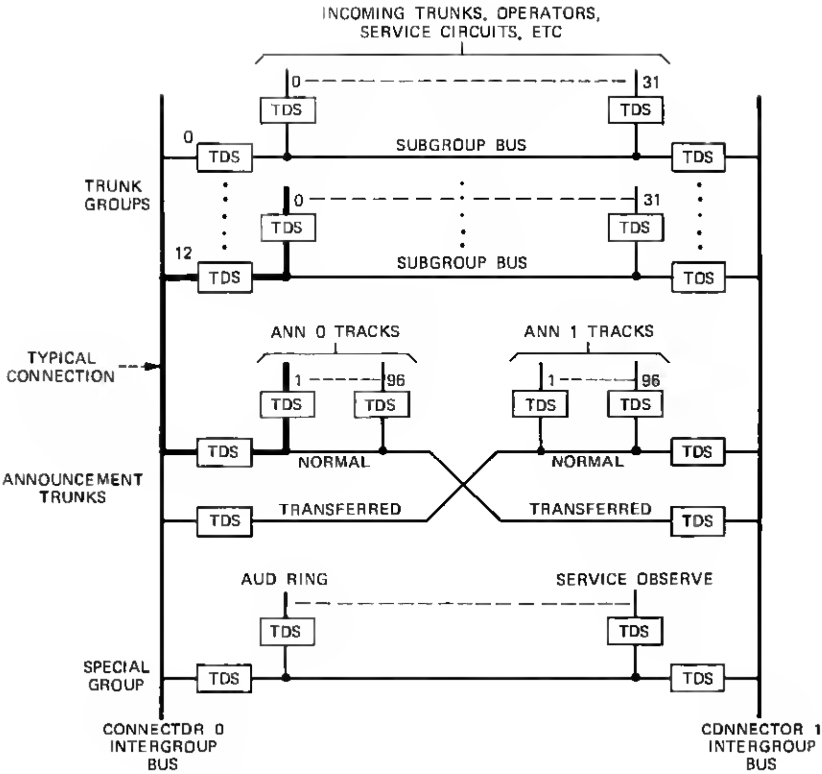

Fig. 12—Time division network buses.

transfer arrangement in the operator trunks. A talking path from one trunk to another is established in a time slot by operating appropriate time division switches. The time division switches of 32 trunks are connected to a subgroup bus. Thirteen subgroup buses are required to accommodate the 415 trunks; each bus has 2 TDS allowing it to be connected to either intergroup bus. Each network has two intergroup buses, eacb associated with a connector circuit which controls 32 talking time slots.

Trunks of the two announcement machines appear on separate buses. A program-controlled flip-flop within the connector selects the announcement machine to be used by a particular connector. In addition, a special group is provided so that a three-way connection can be established to include service observing or audible ringing.

4.2 Connector and scanner circuit

A network contains two connector and scanner circuits, two clocks, and one transfer and alarm circuit. The transfer and alarm circuit and one of the duplicated connector and scanner circuits are shown in Fig. 13. The transfer and alarm circuit is used (*i*) to remove a faulty connector and its clock and scanner from service; (*ii*) to change the announcement configuration; and (*iii*) to select the online clock and scanner.

A 3.25-MHz clock is used to control all data manipulating, gating, and time division switch closure signals. The two connectors are interlocked to insure that only one connector is establishing a connection at a particular instant of time. The clock which is placed on line by the transfer and alarm circuit drives both connectors. A time slot counter driven by the clock establishes a number of time intervals or time slots (TS) which are assigned to three functions as shown in Fig. 14: (*i*) connection control (TS 0–31); (*ii*) processor communication (TS 32); and (*iii*) autonomous trunk scanning (TS 33 and 34). Each time slot interval is 2.464 μs long. As shown in Fig. 14, the connector whose scanner is on line recycles in 86.24 μs; the other connector recycles in 83.78 μs because it skips one of the

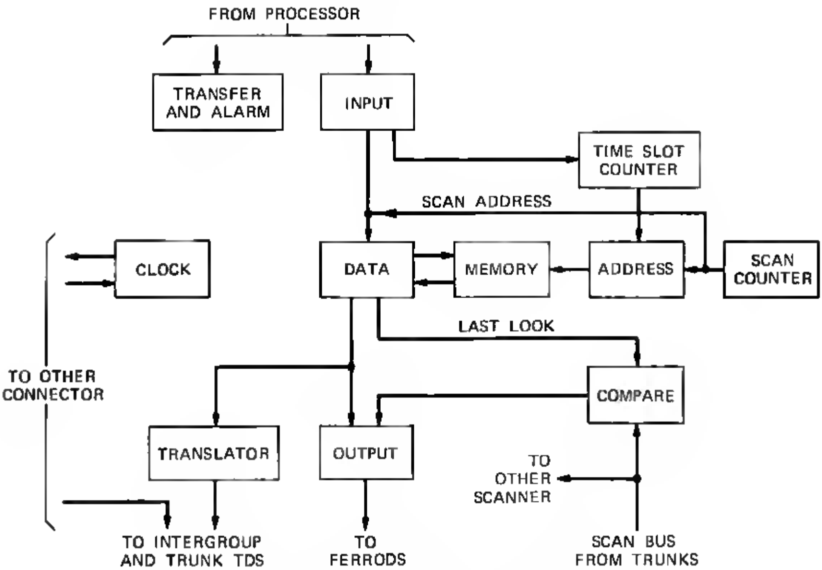

Fig. 13—Connector and scanner circuit.

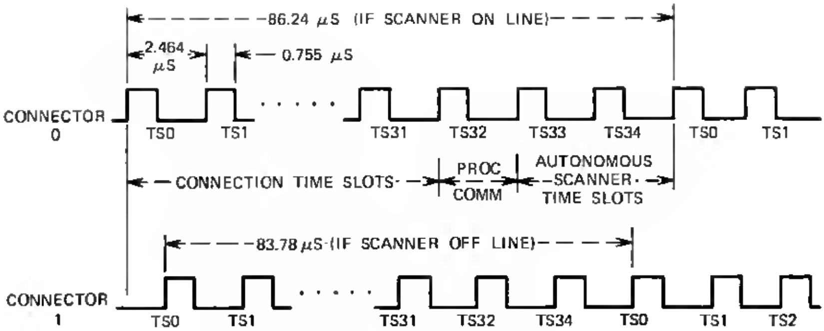

Fig. 14—Time division switch timing.

autonomous scanner time slots, TS 33. This causes the time slots of the two connectors to precess, preventing crosstalk.

4.2.1 Connection control

During TS 0–31 the connector uses data stored in the connector memory to establish talking connections. The memory contains 32 time slot words, one for each talking time slot, and 26 words used by the autonomous scanner described later. Each word is 24 bits long. The connector reads the trunk numbers which are to be connected together from one of the 32 time slot memory locations selected by the time slot counter (Fig. 13). A trunk number consists of group, vertical, and horizontal digits, each made up of three bits. Each nine-bit trunk number is translated into three 1-out-of-8 select signals (G, V, H) which operate the appropriate TDS. Figure 12 shows a connection to an announcement trunk which requires the closure of four TDS. While the connection is in progress, a test is made to verify that the proper number of TDS have closed. A connector closes the TDS for 0.755 μs of the 2.464-μs time slot interval. The remainder of the 2.464-μs interval is used for data manipulation and for TDS closures by the other connector. To prevent crosstalk from one time slot to the following time slot, the time division buses are discharged by clamping to ground after each TDS closure.

4.2.2 Processor communication

During TS 32, the connector checks the input register for requests from the AIS processor. The processor can request that a new connection be written into the memory, request a readout of a memory location, or request a directed scan of a particular trunk to determine its present state (on-book or off-hook).

4.2.3 Autonomous scanner

The autonomous scanner of one connector monitors the supervisory states of all trunks on tbe network. The scanner contains a nine-bit scan counter which identifies tbe trunk to be scanned. During TS 33 and 34 one trunk is scanned by gating the scan counter to the data register, whicb causes tbe translator to select the appropriate trunk (Fig. 13). In response, tbe selected trunk sends back a status signal to the scanner over tbe scan bus. There is a last-look bit in the memory corresponding to each trunk. Tbe last-look bits are stored 16 to a word; thus 26 words are needed to accommodate the 415 trunks. The five higb-order bits of tbe nine-bit scan counter are used to read the memory at one of the locations. After comparing a trunk's present state with its corresponding last-look bit, the autonomous scanner advances to the next trunk if no change has occurred. If a cbange is detected, the scanner stops scanning, the last look memory is updated, and a message identifying the trunk and its present state is loaded into the output register which controls ferrods on the master scanner. Call processing programs check for autonomous scanner messages once every 25 ms. When a call processing program has read the scanner message, it signals the scanner to continue scanning. The scanner can scan one trunk during each TS 33, which occurs once every 86.24 μs. Thus, if no change is detected, the 415 trunks can be scanned in 36 ms.

The connector and scanner maintenance programs initialize the last-look and time slot memory wbenever it may be in error. A scanner switch or a clock switcb will be followed by a memory update which uses call processing records in call store to reinitialize the connector's memory. After the update is completed, tbe scanner is switched on line, and it begins scanning from the first trunk.

4.3 Connector and scanner fault detection and recovery

Connector and scanner faults are detected by call processing, audits, and trunk maintenance programs as well as connector and scanner maintenance programs. When a failure is detected, a connector and scanner working mode program establishes a working configuration and requests tbe appropriate diagnostic.

The equipment in the peripberal system is duplicated and connected to the processor's communication buses, whicb are dedicated

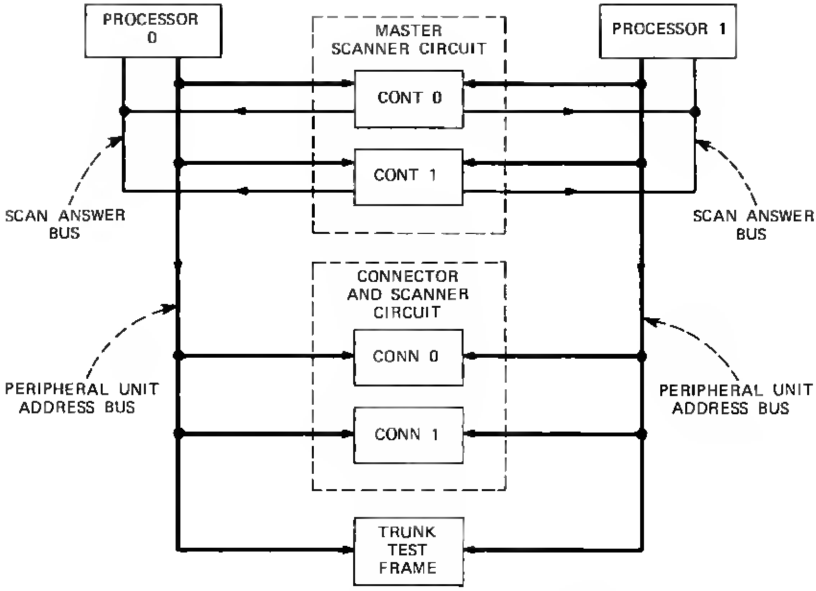

Fig. 15—Duplication oi important network circuits.

to the corresponding processors as shown in Fig. 15. Because of the dedicated busing, a peripheral unit fault recovery or working mode program must switch the processor online configuration in order to change the bus access to a peripheral unit. If the working mode program identifies a problem in the interface between a processor and a peripheral unit, the processor is removed from service and the appropriate processor-peripheral unit diagnostics are requested.

Figure 16 shows the strategy used by the connector and scanner working mode program to establish a working configuration and request the proper diagnostic. When a connector and scanner working mode program is called with a failure, the working mode program retries the failing operation and, if there is no error on the retry, it increments a transient error count. If the retry fails, the online processor is placed off line and the standby processor goes on line. With the new processor on line, the order is retired again. If it fails again, the connector is removed from service and an online connector diagnostic is requested. If the second retry passes, the offline processor is removed from service and an offline connector diagnostic is requested. Since the connector is functioning properly with the online processor, the connector remains in service.

Some operations cannot be retried, others have the property of always passing when retried if certain faults are present. To cover these cases the working mode program monitors the error rate (see Fig. 16). When the rate becomes excessive, the equipment is reconfigured and the rate is monitored again. If a connector has an excessive error rate with both processors, the working mode program removes the connector from service and requests an online diagnostic. If a connector has an excessive error rate with a single processor, that processor is removed from service and an offline diagnostic is requested for the connector.

4.3.1 Fault detection—call processing

Call processing programs can detect errors on most operations they request the connector and scanner to perform. The reaction to a failure of any of these requests is similar to the two described below.

Call processing programs check the connector and scanner each time they establish a connection or scan a trunk. When data are sent to the connector, the circuit sends an enable verify signal back to the processor to indicate that it has received the data. If the circuit fails to send back this signal, the program calls in a connector and scanner working mode program.

When the autonomous scanner sends a message to the call processing program, the program compares the trunk status change with its records. An unexpected change of state (e.g., an off-hook from an unequipped trunk) will cause the call processing program to call a working mode program which will increment an autonomous scanner error counter. The autonomous scanner operations cannot be retried, and so the working mode program monitors the rate at which errors are detected. When the autonomous scanner causes ten errors within a ten-minute interval, the working mode program removes the circuit from service and requests an online diagnostic.

4.3.2 Fault detection—audits

An audit program is able to detect connector and scanner errors as it checks the data associated with the intercept connections.[6] The program can detect when data fail to be transmitted to the connector memory properly. It also can detect memory addressing errors, which can cause data to be overwritten by a subsequent connection.

If a time slot readout error is detected, the time slot readout working mode program retries the failing operation by retransmitting

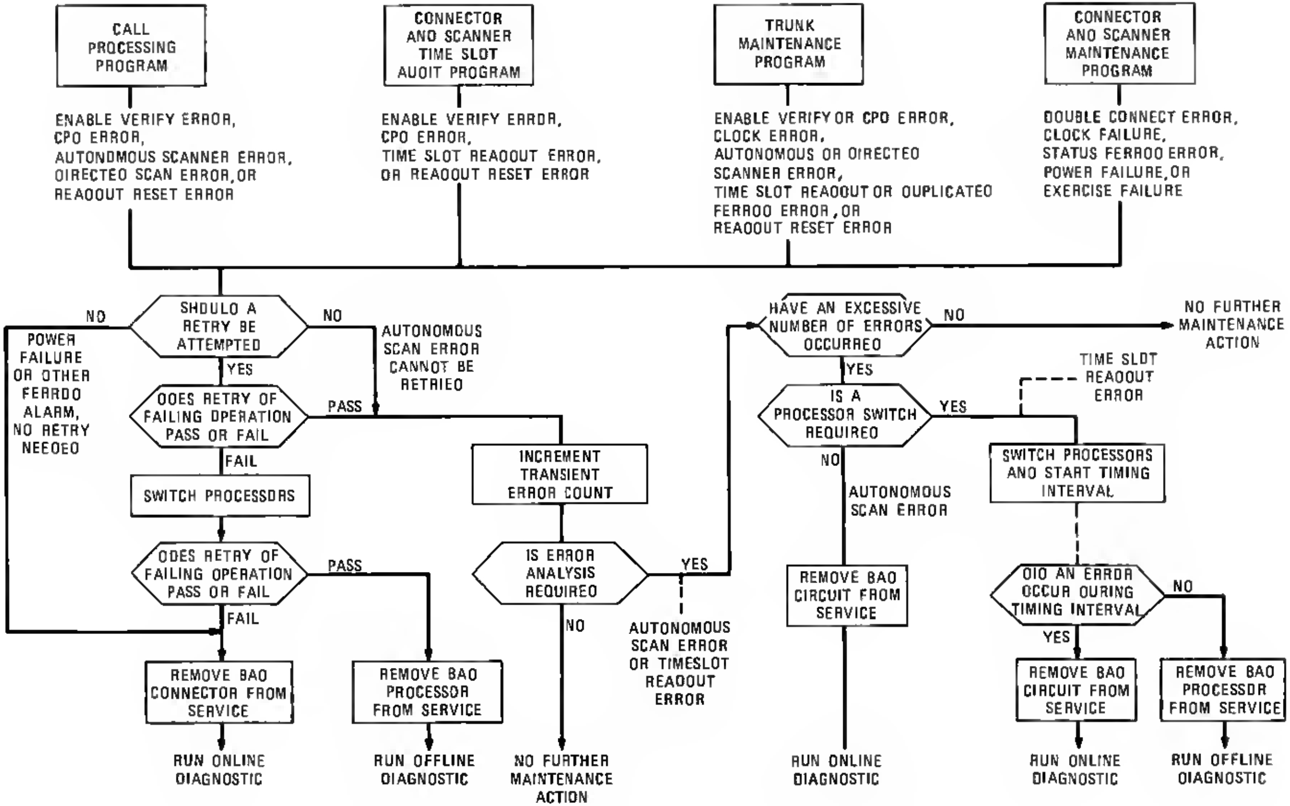

Fig. 16—Connector and scanner fault detection and recovery.

the connection data and then rereads the time slot memory. If the retry passes, a time slot readout transient error counter is incremented. If the failure persists, the processors are switched and the retry is repeated again and a connector and scanner diagnostic is requested.

If memory addressing faults are causing data to be overwritten, retries of a specific failure will always pass. Therefore, the time slot readout working mode program monitors the transient error rate. If the program detects four transient errors within ten minutes, it will cause a processor switch. If no further errors occur for over two minutes, the offline processor is removed from service and the connector offline diagnostic is requested. If errors continue to occur, the connector is removed from service and an online diagnostic is requested.

4.3.3 Fault detection—trunk maintenance

The trunk maintenance programs systematically test the ability of the network to scan trunks and to transmit audio signals. These programs force the trunk under test off-hook and on-hook by applying and removing seizures using the trunk test circuit. The trunk state changes reported by the autonomous scanner are verified by a directed scan of the trunk. If a trunk state change occurs but it is not detected by the autonomous scanner within four seconds, the trunk maintenance program calls the autonomous scanner working mode program. On the other hand, if both the directed scan and the autonomous scan results are incorrect, the failure is attributed to the trunk being tested.

Failure of TDS clock signals can cause excessive noise or transmission failures. Therefore, if the trunk and service circuit diagnostic detects these failures it will switch clocks and repeat the failing test. If the test continues to fail with the new clock on line, the failure is attributed to the trunk. If the test fails with only one clock, that clock is marked out-of-service. Because of the close relationship between trunk and network operations, the trunk and service circuit maintenance programs are an important mechanism for detecting problems in the interface between the connector and scanner and the trunk and service circuits.

4.3.4 Fault detection—connector and scanner maintenance

Alarm ferrods report closure of an improper number of TDS, voltage alarms, and the configuration of the clock, scanner, and connector. Connector maintenance programs monitor these ferrods and remove and diagnose the appropriate circuit if a trouble is indicated. Once a day the entire diagnostic is run in an exercise mode on each connector to insure that all maintenance and redundant circuitry is functioning properly.

4.4 Connector and scanner exercise and diagnostic programs

There are three test control programs: exercise, online diagnostic, and offline diagnostic (see Fig. 17). There are nine connector and scanner maintenance test blocks which are used by the control programs to test the connector and scanner. These tests can be requested automatically by a working mode program or manually via the teletypewriter. The test blocks are run in an order such that a circuit used to test another circuit has itself been previously tested. For example, the time slot and autonomous scanner last-look memory is checked before testing the autonomous scanner. Therefore, when the autonomous scanner last test is run, the circuitry under suspicion does not include the last-look memory. When a test fails, the diagnostic program will generate a TTY printout containing a trouble number. A trouble locating manual cross references trouble numbers to circuit packs to be replaced.

The general features of the three control programs include removing the connector from service, sequencing through the tests, forming the appropriate printout, and, if possible, restoring the connector to service. The exercise control program tests a network if both connectors are in service. After testing both connectors, a network is initialized with a different clock and scanner configuration. After an automatically requested connector online diagnostic, the control program will restore the connector to service if all tests passed. The offline diagnostic control will restore a connector to its original status when the diagnostic is complete. That is, whether

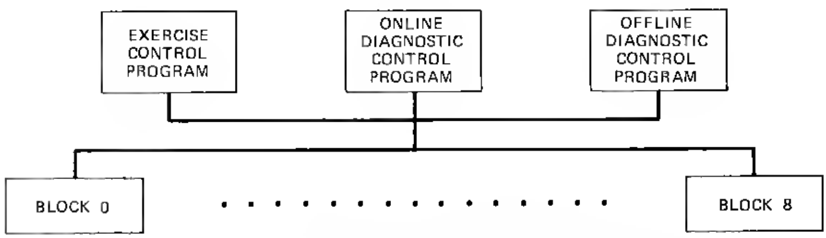

Fig. 17—Connector and scanner exercise and diagnostic.

the diagnostic fails or passes, a connector which was on line will be restored to service, since it operates satisfactorily with the online processor. A manual request can instruct a test control program to run a complete exercise or diagnostic or a small part of a diagnostic. For example, a single test block or a test segment may be run separately.

4.4.1 Connector and scanner removal from service

When a circuit is going to be tested, the control programs and the working mode programs can cause the connector to be removed from service "gracefully" or "hard." A "graceful" removal allows the calls in progress to complete before starting the test. On the other hand, the "hard" removal causes any calls which were in progress to be immediately removed from the time slots and routed to operators via the other connector. The online diagnostic will only "hard" remove when the fault has affected the calls which were in progress (for example, a fault in the connector memory). The exercise and offline diagnostic control programs always "gracefully" remove a connector from service.

4.4.2 Offline diagnostic

If the working mode program encounters a processor-connector interface problem, the processor is removed from service and an offline diagnostic is requested. The connector offline diagnostic is preceded by a diagnostic on the offline processor. If the processor diagnostic passes, the connector offline diagnostic program tests the interface between a processor and a connector. Figure 18 shows the functions performed by the two processors during an offline diagnostic. The control program in the online processor must wait for an interval during which no peripheral orders will be issued from the online processor. The autonomous IO circuit in the online processor sends orders to the peripheral system every 1.25 ms. Also the connector and scanner offline diagnostic control program running at base level in the online processor may be interrupted by IO25 or file interrupts. Programs in these interrupt levels in the online processor may also send orders to the peripheral system. When an interval is found in which there will be no IO circuit activity and no IO25 or file interrupts, the offline processor is started and may send peripheral orders without interfering with the work of the online processor. The tests run in the offline processor are segmented into short 640-μs sections. After completing a section, the connector

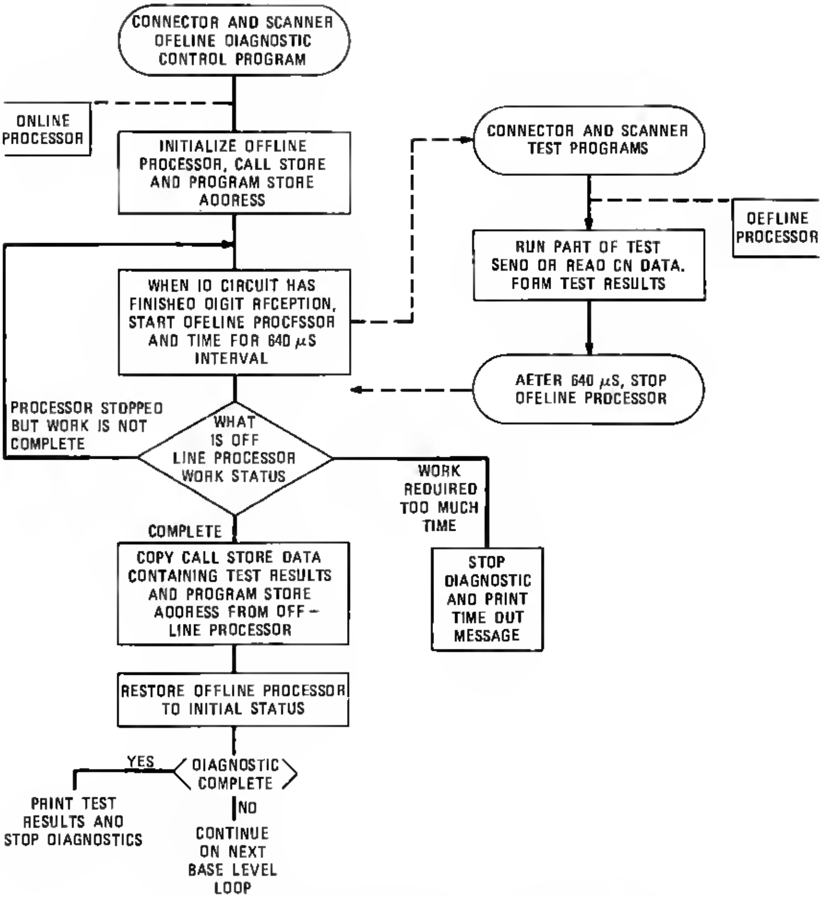

Fig. 18—Connector and scanner offline diagnostic.

and scanner diagnostic program running in the offline processor stops the offline processor.

While the offline processor is executing a test, the control program in the online processor times for 640 μs. At the end of this interval it checks the status of the offline processor. If the offline processor has stopped but has more work to do on this base level loop, the control program will locate another noninterfering time interval and allow the offline processor to execute another section.

When the offline processor has completed the work which is to be done on this base level loop, it signals the control program in the online processor to return to the maintenance monitor. The offline diagnostic control program then copies data from the offline call store and restores the offline processor to its initial status. If the diagnostic is not finished, it will be continued on the next base level loop. If the diagnostic is complete, appropriate TTY messages are printed.

V. CENTRALIZED INTERCEPT BUREAU (CIB)

Most intercept traffic is handled automatically by the AIC without need of human intervention. However, a small number of calls—less than 5 percent—require the assistance of an operator. When a call is routed to an operator, all available data about the call are sent to the position via a data outpulser and displayed in front of her. In some cases, such as the dissolution of partnership where tbere is more than one new number, the information is not placed on the disc file and the operator may bave to refer to a small position record. The operator console and a typical display are shown in Fig. 19.

5.1 CIB position

The operator has the ability to interrogate the disc file to obtain information about a number other than the one displayed. To convey her request to the processor, the operator seizes an inquiry trunk to the appropriate AIC and MF keypulses the necessary digits to an MFR. After keying, her old display is erased and replaced by the new display. She also can elect to hear an announcement regarding the keyed number but this is rarely done because of excessive operator bolding time.

Sbould it become necessary, sbe may transfer a customer to tbe service assistant or she may include the service assistant for a conference. The operator is also able to extend the call via a subscriber line circuit should the occasion arise. Tie lines are also provided at the position so the operator may have access to the service order bureau or to the repair service desk.

The position has been designed for ease of installation. Since very few leads connect from one position to another, adding, removing, or changing positions in the field is a very simple operation. Tbe position is designed with plug-in connectors and circuit packs and requires a 24 V power source. Since each position is self-contained, tbe maintenance program is considerably simplified over that which would be required if positions sbared common equipment.

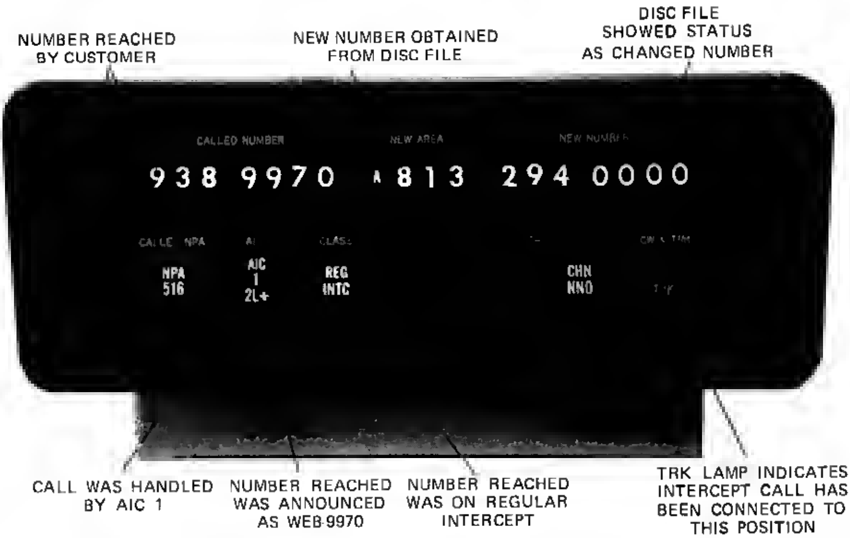

Fig. 19—CIB position and typical display.

5.2 ONI position

Although the CIB may also be used to handle ONI traffic for the home AIC, for those AIC which have a large amount of ONI traffic a special-purpose operator position is used. Since the ONI position is only used for the operator number identification function, it is less expensive than a CIB position which has data receiving and display circuitry. On an ONI call the operator interrogates the customer to obtain the called number and keys this number into the AIC. Since MFR usage is so great in an ONI position, the MFRs are dedicated to each position and not switched through the network. A special MFR test trunk may be automatically connected to any dedicated MFR to provide a network appearance to allow program tests.

The ONI positions are administered as a separate operator group. An ONI operator group is required at a remote AIC if that AIC handles ONI traffic. The home AIC has a night transfer arrangement which permits closing the ONI group of the home AIC and allowing the CIB group to handle all traffic.

5.3 Operator training

A maximum of two CIB positions may be used for operator training. During periods of training, the processor will not allow service traffic to be directed to a training position. A standard 12-button *Touch-Tone* card dialer plugs into the position, or may be remotely located, and terminates in a dedicated incoming trunk at the AIC. The trainer uses the card dialer to outpulse intercepted numbers. This training call will then be connected to the training position with a display. All types of incoming traffic can be simulated in this manner.

5.4 Administrative and maintenance features

Various features are provided to assist traffic and plant personnel with the operation of the system.

5.4.1 Operator group displays

A lamp signal cabinet is furnished at the CIB and ONI position locations. The lamps in this cabinet indicate the following:

(*i*) Position occupied.
(*ii*) Position busy or idle.
(*iii*) Calls are waiting to be served.

(*iv*) An excessive number of calls are waiting to be served.
(*v*) Service affecting trouble exists at the AIC.
(*vi*) Position on training.
(*vii*) Night transfer of ONI to CIB in effect.

5.4.2 Operator-keyed troubles

Instead of filling out paper tickets, operators report troubles by keypulsing a three-digit trouble code into the AIC. When an operator-keyed trouble report is received, the maintenance TTY will print the position number reporting the trouble, the incoming trunk number, and the time slot associated with the call. These trouble reports have been used to locate troubles not only in the AIC and CIB but also in the local offices, concentrators, and other switch trains connecting to the AIC.

5.4.3 Test codes

Craftsmen may request test setups for position trunks by MF keypulsing three-digit test codes from the position. A series of codes are reserved to request various test displays from the AIC. Other codes request connections to transmission test lines such as quiet termination, 1000-Hz milliwatt generator, or a jack-ended test line.

Craftsmen in local offices may also reach these test lines in the AIC by keying similar test codes over incoming intercept trunks. In the case of trunks which are immediately connected to operators (directory assistance, ONI), the craftsman at the local office may seize the trunk and then request the operator to key the test code to transfer his trunk to the test line.

5.4.4 Service observing

Service observing (SO) is provided on intercept calls connected to operator positions. A high-impedance trunk appears on the time division network and is bridged onto the connection when an observation is being made. This trunk is connected to a service observing desk which is also shared with other systems. The AIC transmits information pertaining to the call to the service observing circuit which forwards it to the desk where it is displayed in front of the service observer.

VI. CONCLUSION

The AIS peripheral circuits, consisting of the time division network, announcement machine, and trunk and service circuits, have been described. Maintenance techniques consisting of both hardware and software features have been integrated to achieve a reliable system.

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